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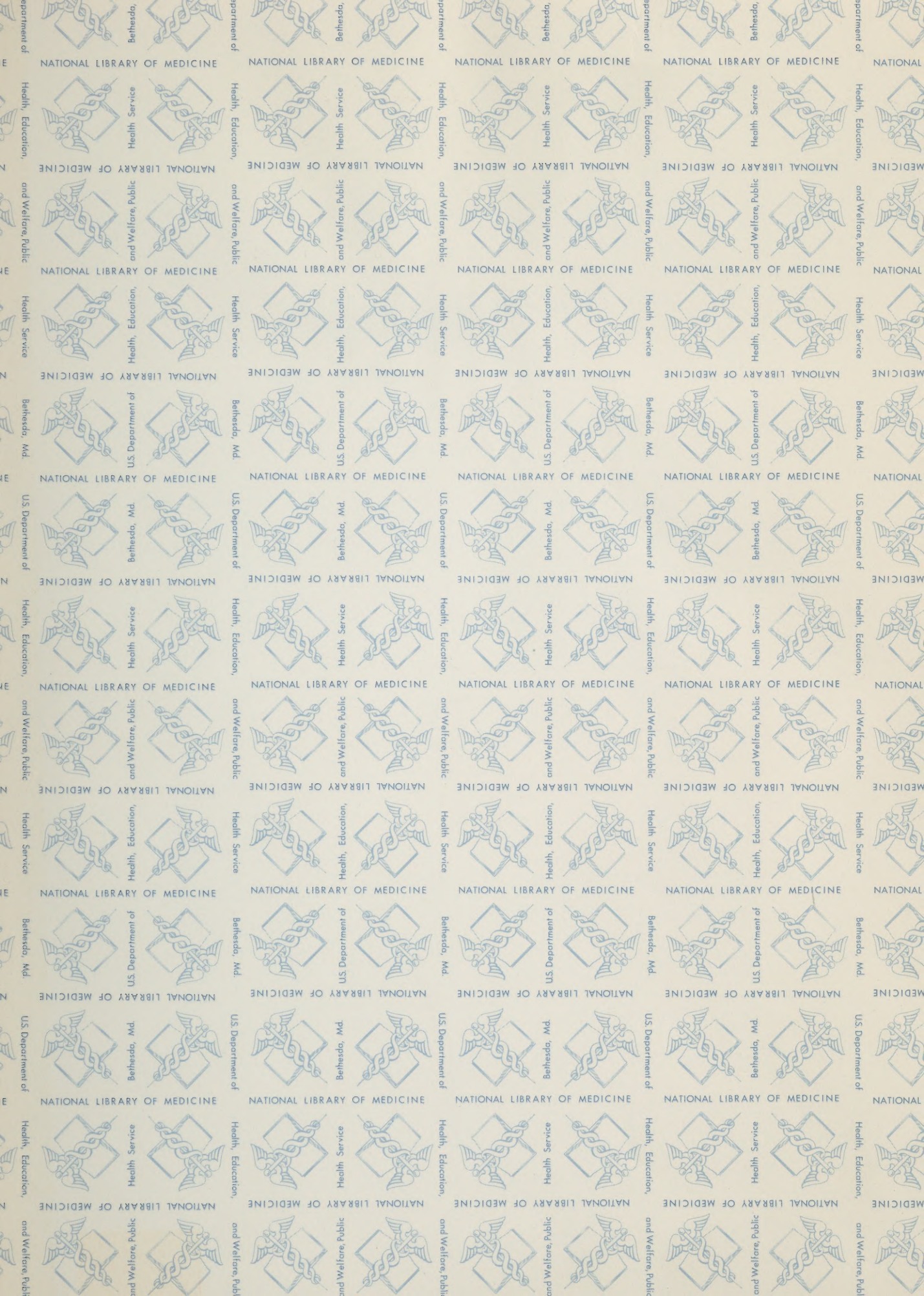
Effect Of Large-Scale Methods Of Preparation On Vitamin Content Of Food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THE EFFECT OF LARGE-SCALE METHODS OF PREPARATION ON THE VITAMIN CONTENT OF FOOD:

II. THE CAROTENE, ASCORBIC ACID, NIACIN, THIAMIN, RIBOFLAVIN, PANTOTHENIC ACID, AND BIOTIN CONTENT OF CARROTS

Headquarters, Military District of Washington Nutrition Laboratory
Office of the Pentagon Post Restaurant Officer
The Pentagon Washington 25, D. C.

Army.
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Investigation and Report by:

Fred G. Koch, Major QMC
Post Restaurant Officer
The Pentagon

Frank Streightoff
1st Lt., Sn. C., AUS
Nutrition Officer

Dr. Hazel E. Munsell
Dr. Ben-Ami Ben-Dor
Martha Louise Orr
Mary Haines Leonard
Sarah R. Ezekiel

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Carrots are the most important source of carotene in the Army garrison ration and in the quantity consumed they are their third most important vegetable. Data available at the present time on vitamin retention in carrots are scant. It was the purpose of this study to determine vitamin losses in the large-scale preparation of carrots.

REVIEW OF THE LITERATURE

Carotene. A review of the literature shows the carotene content of carrots to vary from 25.6 mg. (1) to 2.3 mg. per 100 gm. (2). A value of 12,000 I. U. vitamin A (7.2 mg. beta-carotene) per 100 gm. has been selected for the edible portion of fresh carrots (3).

Values for carotene presented in the literature are given variously in terms of "carotene", "crude carotene", and "beta-carotene." Recent work has shown that "crude carotene" consists of several carotenoid pigments of varying biological activity. Of these carotenoid pigments, only alpha and beta carotene are present in carrots in important quantities (4). Alpha carotene has been reported as having half the biological potency of beta carotene (5). Harper and Zscheile (6) reported that the carotene of a number of garden varieties of carrots contained on an average - 46 per cent alpha carotene. Kemmerer and Fraps (4) found that the carotene of a number of samples of raw carrots contained 20 to 36 per cent alpha carotene and of boiled carrots, 23 to 41 per cent.

Harper and Zscheile (6) observed that frequently the depth of external coloring of a carrot is a rough index of the carotene concentration. In each variety of carrots studied except the Belgium White they found the carotene content of the phloem was greater than that of the xylem per unit length of root.

Peterson (7,8) reported losses of carotene in the large-scale preparation of boiled carrots to be 6 to 23 per cent, buttered carrots 12 to 13 per cent, and creamed carrots 9 per cent. Oser, et al. (9) prepared carrots in household quantities by waterless cooking and by boiling and found carotene losses of 4 and 6 per cent respectively. Pyke (10) obtained data which suggested no loss of carotene when carrots were steamed.

Fenton and coworkers (11) in a study of dehydrated carrots reported losses of carotene of 0 per cent in simmering in a stock-pot for 30 min.; 19 per cent in bringing to a boil (45 min.) and simmering 20 min.; 5 per cent in pressure steaming (15 min.); and 1 per cent in boiling 25 min. In cooking dehydrated carrot bricks 11 per cent of the carotene was lost in bringing them to a boil (45 min.) and simmering 20 min.

Ascorbic Acid. The ascorbic acid content of the carrot varies markedly. Two extreme values are 31 mg. (12) and 0.8 mg. per 100 gm. (13). A value of 6 mg. per 100 gm. is given for the edible portion of fresh carrots (3). The ascorbic acid concentration also varies between different parts of the carrot. Rudra (12) in his work on the Indian carrot found the skin to contain 75 mg. per 100 gm. and the flesh 31 mg. per 100 gm.

Reported losses of ascorbic acid in boiling of carrots average 61 per cent (1, 7, 8, 14-19), and range from 43 per cent (14) to 77 per cent (15). Most of these data were obtained in large-scale cookery. Data reported for ascorbic acid losses after steaming of carrots by institutional methods vary over the small range of 47 to 52 per cent (10, 14, 20). Similar results were obtained by Brinkman, et al. (17) who cooked carrots in a pressure saucepan and in a waterless cooker and found losses of ascorbic acid of 55 and 50 per cent respectively; and by Peterson (7, 8) who reported losses of 49 and 51 per cent in the preparation of buttered and creamed carrots. Daum, et al. (21) found on the other hand a 25 per cent loss in carrots prepared by an unspecified institutional method.

Many investigators have reported losses of ascorbic acid in cooked carrots held on a steam table for various lengths of time (10, 14, 17, 18, 20, 21). A typical example was reported by Higgins (14) who found that carrots which lost 52 per cent of their ascorbic acid during steaming, lost an additional 21 per cent when held on the steam table 1 hr. Capps and Flanagan (22) found that destruction of ascorbic acid increased as the cooking period was lengthened. Carrots boiled 15 min. lost 47 per cent ascorbic acid but those boiled 60 min. lost 60 per cent.

Niacin. The niacin content of raw carrots as reported in the literature varies from .22 mg. (23) to .71 mg. per 100 gm. (1). A value of .5 mg. per 100 gm. has been selected for the edible portion of fresh carrots (3).

Oser, at al. (9) prepared carrots in small quantities by a waterless method and by boiling and found losses of niacin of 1 and 29 per cent respectively. Heller, et al. (15) found a loss of 45 per cent in carrots boiled in large quantities. Data on niacin content of raw and cooked carrots reported by Pyke (10) would indicate a loss of 14 per cent when calculated on the dry weight basis.

Fenton and coworkers (11) in an investigation of dehydrated carrots found niacin losses of 52 per cent in simmering in a stock-pot 30 min.; 43 per cent in bringing to a boil (45 min.) and simmering 20 min.; 58 per cent in pressure steaming; and 42 per cent in boiling. In cooking dehydrated carrot bricks 42 per cent of the niacin was lost in bringing them to a boil (45 min.) and simmering 20 min.

As this vitamin is quite heat stable, the "lost" portion can usually be found in the cooking water; for instance, Russell, et al. (24) found 72 to 85 per cent of the original niacin content in the cooked carrots, and 5 to 12 per cent in the cooking water.

Thiamin. The thiamin content of raw carrots as reported in the literature varies from .025 mg. (23) to .100 mg. per 100 gm. (25). A value of .07 mg. per 100 gm. has been selected for the edible portion of raw carrots (3).

Heller, et al. (15) in their study of large-scale cooking reported that 52 per cent of the thiamin was lost in boiling. Nagel and Harris (20) studied the effect of an institutional method of steaming and reported a 25 per cent loss. Fenton and coworkers (11) found thiamin losses in preparation of dehydrated carrots of 43 per cent in simmering 30 min.; 25 per cent in bringing to a boil (45 min.) and simmering 20 min.; 48 per cent in pressure steaming; and 48 per cent in boiling (25 min.). In cooking dehydrated carrot bricks 43 per cent of the thiamin was lost in bringing them to a boil (45 min.) and simmering 20 min. Hinman, et al. (17) found an average thiamin loss of 4 per cent in family size portions of canned carrots prepared by concentrating the liquid, adding the solid portion and heating. When the same investigators boiled canned carrots by a typical Army method (18) they found that the boiled carrots contained only 64 and 68 per cent of the original thiamin content and the boiling water 30 and 27 per cent. The actual thermal destruction of thiamin, amounted, therefore, to only 5 and 6 per cent.

Riboflavin. The riboflavin content of raw carrots as reported in the literature varied from .040 to .10 mg. per 100 gm. (23). A value of .06 mg. per 100 gm. has been selected for the edible portion of fresh carrots.

Heller, et al. (15) in their study of large-scale cooking found a loss of 61 per cent riboflavin when carrots were boiled. Pyke (10) found a loss of 7 per cent (calculated on the dry weight basis) in carrots boiled in an Army Student Training Program mess. Fenton and coworkers (11) prepared dehydrated carrots in a number of ways and found riboflavin losses of 26 per cent in simmering 30 min.; 11 per cent in bringing to a boil (45 min.) and simmering 20 min.; 35 per cent in pressure steaming; and 39 per cent in boiling. In cooking dehydrated carrot bricks 45 per cent of the riboflavin was lost in bringing them to a boil (45 min.) and simmering 20 min. Hinman, et al. (17) found slight gains of riboflavin when canned carrots were heated in the concentrated canning liquor as described above.

Pantothenic Acid. The literature available on the pantothenic acid content of carrots is at present scant. Values reported range from .12 mg. (23) to 3.2 mg. (1) per 100 gm. Pyke (10) reported data on raw and cooked carrots which would indicate a loss of 17 per cent of pantothenic acid in cooking, when calculated on a dry weight basis.

Biotin. Cheldelin and Williams (26) reported that 4 samples of carrots contained an average of .0025 mg. biotin per 100 gm.

PLAN OF THE EXPERIMENT

The general plan for this investigation was similar to that followed in a previous study on potatoes (27), except that the methods of preparation were limited to boiling and steaming. For each of these methods of preparation, determinations were made on a sufficient number of replicate samples, usually 10, to furnish data suitable for statistical analysis.

The plan of determining the batch weights at successive stages in the preparation was used as previously described (27). It was of particular value in the case of carrots since the leaching of solid matter into the cooking water was even more marked than in the case of potatoes.

The analyses included determinations of dry solids, hydrogen ion concentration, and content of carotene, ascorbic acid (total and dehydro), niacin, thiamin, and riboflavin. Through the kindness of Dr. C. A. Elvehjem, pantothenic acid and biotin determinations were made at the Department of Biochemistry, University of Wisconsin, on composites prepared from the replicate B-complex samples.

Study I. The carrots for this study were obtained from the general supply for the Pentagon Post Restaurants. The different batches of carrots varied considerably in size, depth of color, degree of maturity, freshness, and variety. Differences in vitamin content from batch to batch were also marked.

Study II. To eliminate some of the variables obtained in the first study, a second study was made with carrots of a single variety and of a single purchase-lot. Twelve crates of the Chantenay Coreless variety were obtained from a producer in the Imperial Valley, California. The carrots were received in prime condition with tops. After a week's storage, it was necessary to remove the tops from all the remaining carrots to reduce wilting and deterioration from fungus diseases.

EXPERIMENTAL PROCEDURE

Methods of Preparation of Carrots and Selection of Samples

The methods of preparation selected are those used in the Army mess and other installations where large numbers of people are fed. In some installations carrots are prepared for cooking by peeling in a mechanical abrasive peeler, and in others they are cleaned with water and a stiff brush. Boiling is a common mess practice and steaming is typical in large restaurants and consolidated messes.

Study I. The batch of carrots intended for a day's run was sorted by setting aside every 10th carrot for the raw unpeeled sample. These carrots were washed by hand, trimmed of tops and roots, and sliced into disks in a powered vegetable slicer with blades set at 3/8 in. This sample was thoroughly mixed and used immediately for preparation of subsamples. This mixing and immediate subsampling was the general practice for all raw samples.

The remaining carrots, approximately 45 lb., were peeled in a mechanical abrasive peeler for 2 min. and then drained. The machine did not peel unsound carrots; these therefore could be detected and discarded. Green and purple epidermis and woody stalk parts were removed. The peeled carrots were then sliced by the machine into one large container and slices from every part of the container were used for the samples for the raw peeled and for the various cooking procedures.

For boiling, about 25 lb. of carrot slices were placed in a 20 gal. tinned iron pot (small areas of iron were usually exposed), and covered with boiling water. The water was then brought back to a vigorous boil, 100 gm. of sugar and 100 gm. of salt were added, and the boiling continued until the carrots were tender, usually 45 min. For steaming, approximately 6 lb. of the carrot slices were placed in 1 gal. stainless steel pans and cooked in a free-venting vegetable steamer until tender, usually 25 min. For holding, quantities of the boiled or steamed slices were placed in 1 gal. stainless steel pans and kept on the steam table for 1 hr.

Samples were prepared of carrots: raw, unpeeled; raw, peeled; boiled; boiled, held 1 hr.; steam; and steamed, held 1 hr. Water from the boiled carrots was also sampled.

Study II. Sixty lb. of Chantenay Coreless carrots were used for each run. An approximately equal weight of carrots was taken from each of the 12 crates. The tops and any green epidermis were removed. The carrots were cleaned in water with a stiff brush, and, without previous peeling, were sliced in the mechanical slicer. The method of distribution of slices among the various samples and the subsequent cooking procedures was the same as in Study I, except that no sugar or salt was added.

Samples were prepared as in Study I except that there was no sample for raw, unpeeled.

When Study II was completed, the remaining Chantenay Coreless carrots (266 lb.) were used for a special study on the relationship of carotene content to the physical characteristics of raw carrots. These carrots were separated into 3 groups according to weight, and a sample from each group prepared for carotene analysis. For a second test, 50 medium weight carrots were arranged according to depth of external coloring. The two darkest, the two lightest, and the two of median coloring were individually assayed for carotene.

Subsamples for Analysis

All subsamples for vitamin assay except those from the boiling water samples were prepared for analysis by slurrying with a stabilizing solution in a Waring blendor, and were stored in brown glass bottles in a refrigerator room maintained at 40° F.

There are considerable variations between the inner and the outer parts and among top, middle, and bottom portions of the carrot. This fact and variations among individual carrots, made it essential that subsamples represent as many slices as possible.

For the subsamples of the raw carrots, large numbers of slices were selected at random from the entire sample. The slices were halved crosswise to give comparable subsamples for total and dehydro ascorbic acid. In the case of the cooked carrots, ascorbic acid subsamples were prepared as for the raw. The remainder of the cooked sample was chopped thoroughly with a knife and mixed before aliquots were taken for the other subsamples.

Subsampling for ascorbic acid assays was completed within 15 min. of the time the samples were received in the laboratory. Subsamples of carrots for the determination of total ascorbic acid were made by slurrying 60 gm. of carrot and 180 ml. of 5 per cent metaphosphoric acid. For the subsample of boiling water, 150 ml. of the water and 50 ml. of 20 per cent metaphosphoric acid were used. Sixty gm. of carrot and 180 ml. of 5 per cent metaphosphoric acid containing 1 per cent thiourea were used in preparation of the dehydro ascorbic acid subsamples. Ascorbic acid assays were made within 24 hr. after preparation.

Subsamples for the determination of niacin, thiamin, and riboflavin were made by slurrying 150 gm. carrot with 300 ml. 0.1 N H_2SO_4. For the subsamples of boiling water, 270 ml. of the water and 30 ml. of 1 N H_2SO_4 were used. A small amount of chloroform was added to the B-complex subsamples. When all runs had been completed for Study II, composite subsamples for the determination of pantothenic acid and biotin were prepared for each stage of preparation by pooling 30 gm. of slurry from each of the 10 replicate B-complex subsamples for that stage.

Subsamples for the determination of percentage dry solids were made by slurrying 75 gm. carrot with 150 ml. distilled water. The boiling water was not diluted. Hydrogen ion concentration was determined on portions of the dry solids subsamples.

Subsamples of raw and cooked carrots for carotene analysis contained 100 gm. of carrot slurried with 400 ml. of 3 per cent KOH in 32 per cent ethanol. These preparations were of such a consistency that representative aliquots for assay could be taken with a calibrated inverted pipette. Subsamples of boiling water contained 150 ml. of the water and 150 ml. of 3 per cent KOH in 32 per cent ethanol.

Methods of Analysis

Carotene was determined by the method of Ben-Dor, et al. (28). Carotene as determined by this method is approximately equivalent to "pure" carotene as determined by the AOAC method. Biotin was assayed according to the procedure of Shull, et al. (29), using the modified basal medium of Shull and Peterson (30). The samples were hydrolyzed for assay by autoclaving with 4N H_2SO_4 for 2 hr. at 15 lb. Extracts for pantothenic acid assay were prepared and assayed according to the procedure of Neal and Strong (31) with the modifications introduced by Ives, et al. (32).

All other determinations were made as previously described (27) with the following exceptions: 1) the incubation period for niacin and riboflavin cultures was uniformly 72 hr., and 2) the riboflavin extracts were prepared by autoclaving the subsamples in the presence of 1N H_2SO_4 at 15 lb. for 30 min.

RESULTS

Data on vitamin content, dry solids and hydrogen ion concentration of carrots at all stages of preparation in each of the two studies are summarized in Tables 1 and 2. For the raw, unpeeled carrots a range as well as the average is given. Tables 1 and 2 also present per cent vitamin retention in the carrots at the different stages of preparation. These percentages are the averages of the percentage retentions calculated for individual batches (27). Since in Study I carrots were peeled before cooking, the per cent retention in that study was calculated on the basis of the raw, peeled carrots as 100. In Study II the carrots were cooked without peeling, and the raw, unpeeled was used as 100.

Differences between per cent values for the various stages and methods of preparation were calculated (Table 3) to determine the relative effects of peeling, boiling, steaming and holding. The significance of each difference was assessed by comparison with the Least Significant Difference (95 per cent) calculated according to Student's t method (27).

The mechanical peeling of carrots brought about significant decreases in concentration of carotene, ascorbic acid (total and dehydro), niacin, thiamin, and riboflavin. On the basis of 100 per cent for the unpeeled, the percentage concentration in the peeled was: for carotene, 95.5 per cent; total ascorbic acid, 94.8 per cent; reduced ascorbic, 94.1 per cent; niacin, 74.7 per cent; thiamin, 86.9 per cent; and riboflavin, 88.5 per cent. Niacin, thiamin and riboflavin are apparently more highly concentrated in the portion removed by peeling. Decrease in weight from peeling the stored carrots (Study I) was 16.7 lb. per 100 lb.

Boiling resulted in highly significant losses of ascorbic acid, niacin, thiamin and riboflavin. For the two studies the losses were as follows: total ascorbic acid, 73 and 58 per cent; reduced ascorbic acid, 79 and 65 per cent; niacin, 47 and 43 per cent; thiamin, 50 and 44 per cent; and riboflavin, 34 and 30 per cent. Loss* of pantothenic acid was 46 per cent and of biotin 18 per cent (Study II). Carotene losses were small in both studies and only one loss was significant, that of 5 per cent in Study II.

For the two studies, the water in which the carrots were boiled contained: 16 and 27 per cent of the total ascorbic acid, 51 and 44 per cent of the niacin, 42 and 38 per cent of the thiamin, and 56 and 42 per cent of the riboflavin present in the raw carrots. The boiling water also contained 41 per cent of the pantothenic acid and 29 per cent of the biotin present in the raw carrots. It is apparent, therefore, that vitamin losses in the boiling of carrots are due largely to extraction by the cooking water.

Steaming also resulted in highly significant losses of total and reduced ascorbic acid. For the two studies the losses were 38 and 37 per cent for total ascorbic acid and 44 and 38 per cent for reduced ascorbic acid. Losses of niacin and thiamin were significant in both studies but not as great as those of ascorbic acid. The losses were 16 and 12 per cent for niacin and 18 and 16 per cent for thiamin. Losses of riboflavin were small and significant only in Study II -- 8 per cent.

*Significance of these losses could not be determined since the assays for each stage were made on single samples composited of aliquots from the replicate samples.

Pantothenic Acid showed a gain of 7 per cent; biotin a loss of 4 per cent and carotene a loss of 7 per cent.*

A comparison shows that the steamed carrots retained a much higher percentage of all vitamins studied than did the boiled carrots. In the two studies the steamed carrots retained 35 and 21 per cent more total ascorbic acid, 35 and 27 per cent more reduced ascorbic acid, 31 and 31 per cent more niacin, 32 and 28 per cent more thiamin, and 26 and 22 per cent more riboflavin. Retention of pantothenic acid was 53 per cent greater, and of biotin 14 per cent greater in the steamed than in the boiled carrots.* Retention of carotene was practically the same for steaming and boiling -- 93 and 95 per cent.

Holding cooked carrots on the steam table for 1 hr. resulted in significant decreases in ascorbic acid content only. Boiled and steamed carrots lost respectively, 6 and 8 per cent of total ascorbic acid (Study II); losses of reduced ascorbic acid were 7 and 16 per cent in Study I and 14 and 24 per cent in Study II.

In carrots cooked or cooked and held, dehydroascorbic acid comprises a greater proportion of the total ascorbic acid present than in raw carrots; the per cent losses of reduced ascorbic acid from cooking and holding were greater than those of total ascorbic acid. In the case of Chantenay Coreless carrots cooked and held 1 hr. the actual content (mg. per 100 gm.) of dehydro ascorbic acid was greater than in the original raw carrots.

The carotene content of the carrots grouped according to weight and of those selected according to depth of external coloring is shown below:

Wt. Range gm.	Total Wt. of Group lb.	Carotene mg./100 gm.
18 - 60	56	7.0
16 - 100	139	7.8
101 - 200	71	8.3

*Significance of these losses could not be determined since the assays for each stage were made on single samples composited of aliquots from the replicate samples.

Color	No. Samples	Carotene mg./100 gm.
Dark orange	2	12.6; 13.4
Median	2	8.0; 11.0
Pale orange	2	6.8; 8.0

These results indicate that carotene content does not vary greatly between large and small carrots of the same variety, but that depth of external coloring is a good index of the carotene content of individual carrots.

Since the various carotene fractions have different biological values as sources of vitamin A, the carotene from one set of samples of raw and cooked carrots was fractionated into alpha and beta carotene. The carotene of raw carrots was 22 per cent alpha and 78 per cent beta carotene. The carotene of the cooked carrots gave values of 19 to 22 per cent alpha and 81 to 78 per cent beta carotene, indicating no significant differences in the proportion of these two components in the raw and cooked carrots.

DISCUSSION

Carotene is the most important vitamin in carrots. The data presented show that carrots cooked by boiling or steaming retain practically all of their original carotene and are thus to be considered at least as valuable as raw carrots as a potential source of vitamin A.

Steaming of carrots results in a markedly greater retention of ascorbic acid, niacin, thiamin and riboflavin than does boiling; the loss of solids is also much less in steamed than in boiled carrots. In addition, steamed carrots have better flavor, brighter color and a more pleasing texture.

Vitamin retentions in the peeled and cooked carrots representing stored carrots of several varieties (Study I) and in the unpeeled and cooked fresh Chantenay Coreless carrots (Study II) showed close agreement. Significant differences between corresponding values from the two studies existed only in the case of, 1) thiamin retentions for carrots boiled and held and 2) of riboflavin retentions for the boiled carrots plus the boiling water. From these results it is apparent that vitamin losses due to cooking peeled stored carrots are similar to those due to cooking of unpeeled fresh carrots.

SUMMARY

A study was carried out for the purpose of determining vitamin content and percentage retention in raw carrots and those cooked by large-scale methods. The effect of holding the cooked carrots on a steam table for 1 hr. was studied.

Calculations of per cent retention were made on the "batch weight" basis. Differences in retention between stages and between the two methods of cooking were statistically examined for significance.

Vitamin content of the raw unpeeled carrots varied moderately in the several miscellaneous varieties but only slightly in the ten batches of the Chantenay Coreless variety.

Averages of the individual values from the two studies and the range in mg. per 100 gm. are as follows: carotene, 9.7 and 7.4 to 12.5; total ascorbic acid, 6.0 and 5.1 to 6.8; reduced ascorbic acid, 5.3 and 4.1 to 6.3; niacin, .82 and .57 to 1.46; thiamin, .068 and .057 to .083; riboflavin, .056 and .041 to .070; pantothenic acid, .22 (no range); and biotin, .0018 (no range.) The concentration of niacin, thiamin, and riboflavin was markedly greater in the portion removed by peeling.

Destruction of ascorbic acid was marked when carrots were boiled or steamed. The retention of ascorbic acid in steamed carrots was more than double that in boiled carrots. There was additional destruction of ascorbic acid on holding the cooked carrots on the steam table 1 hr. The proportion of dehydroascorbic acid increased during cooking and holding.

Retentions of the B complex vitamins studied (niacin, thiamin, riboflavin, pantothenic acid, and biotin) were correlated with their solubilities in water. Steamed carrots retained 82 per cent or more of these vitamins; boiled carrots, 50 to 80 per cent. Most of the vitamins "lost" in boiling were found to be in the cooking water.

Holding of the cooked carrots on the steam table 1 hr. resulted in little or no loss of the B vitamins or carotene. Retention of carotene in cooked carrots was almost complete -- 93 to 96 per cent. Unpeeled fresh carrots and peeled stored carrots on cooking showed similar retention of vitamins.

From the standpoint of flavor, aroma, consistency, and appearance as well as retention of the water soluble vitamins and solids, steaming is recommended as superior to boiling for the preparation of carrots. It is also recommended that, when possible, raw carrots be prepared for cooking without peeling.

Table 1. - Vitamin Content of Carrots, Raw and Cooked by Large-Scale Methods, and Percentage Retentions in the Cooked Carrots

Description of Sample	Batch Wt.	Dry Solids	pH	Carotene Content	Vitamin Content*					Carotene Retention	Vitamin Retention**				
					Ascorbic Acid						Ascorbic Acid				
					Total	Reduced	Niacin	Thiamin	Riboflavin		Total	Reduced	Niacin	Thiamin	Riboflavin
	units	%		mg/100 gm	mg/100 gm		mg/100 gm		mg/100 gm	%	%	%	%	%	%
Carrots, Miscellaneous Varieties (Study I)															
Raw, unpeeled	120.0	13.0	6.2	11.0	5.8	5.1	.95	.069	.052	127	127	130	149	140	140
		12.3-14.1	5.7-6.6	9.9-12.5	5.1-6.8	4.1-6.3	.69-1.46	.057-.083	.041-.070						
Raw, peeled	100.0	12.3	6.3	10.5	5.5	4.8	.71	.060	.046	100	100	100	100	100	100
Boiled	93.7	9.4	5.9	10.6	1.7	1.2	.45	.032	.033	96	27	21	53	50	66
Boiled, held 1 hr.	99.9	9.0	5.9	10.2	1.4	.7	.44	.031	.031	97	25	14	54	52	68
Boiling water	113.6	4.8	5.8	.1[a]	.8	---	.37	.023	.023	1	16	--	51	42	56
Steamed	89.4[b]	12.3[b]	5.9[b]	---	3.6[b]	2.9[b]	.62[b]	.050[b]	.045[b]	---	62	56	84	82	92
Steamed, held 1 hr.	90.4[b]	12.9[b]	5.8[b]	---	3.4[b]	2.0[b]	.62[b]	.047[b]	.043[b]	---	60	40	88	78	89
Carrots, Chantenay Coreless (Study II)															
Raw, unpeeled	100.0	12.5	6.1	8.4	6.3[c]	5.7[c]	.64	.066	.062	100	100	100	100	100	100
		12.0-13.0	6.0-6.3	7.4-9.6	5.8-6.6	5.1-6.1	.57-.70	.063-.069	.054-.068						
Boiled	91.9	9.5	6.0	8.7	2.8[c]	2.2[c]	.40	.044	.047	95	42	35	57	56	70
Boiled, held 1 hr.	95.4	9.3	6.0	8.4	2.4[c]	1.2[c]	.38	.040	.045	95	36	21	57	58	70
Boiling water	81.7	5.0[c]	5.8[c]	0.1[d]	1.8[e]	---	.33[e]	.030[e]	.031	1	27	---	44	38	42
Steamed	90.7	12.6	6.1	8.7[d]	4.4[c]	3.8[c]	.62	.061	.062	93	63	62	88	84	92
Steamed, held 1 hr.	91.0	12.6	6.0	8.7[d]	3.8[c]	2.4[c]	.60	.062	.063	93	55	38	86	85	92

*Values are averages of results from a number of replicate batches - usually 10-14. Averages based on less than 10 replicates are indicated as follows: a, 6 replicates; b, 4 replicates; c, 9 replicates; d, single samples composited of aliquots from the sub-samples of various runs; e, 8 replicates.

**Per cent retention in the stored carrots (Study I) was calculated on the basis of the raw peeled as 100; in the case of the fresh carrots (Study II), the raw unpeeled was used as 100. The per cent retention values presented are averages of per cent retentions calculated individually from results for each batch.

Table 2

The Biotin and Pantothenic Acid Content and Percentage Retention of Chantenay Coreless Carrots, Raw and Cooked by Large-Scale Methods

	Vitamin Content*		Vitamin Retention	
	Pantothenic Acid	Biotin	Pantothenic Acid	Biotin
	mg/100 gm.		%	
Raw, unpeeled	.22	.0018	100	100
Boiled	.13	.0016	54	82
Boiled, held 1 hr.	.15	.0016	65	85
Boiling water	.11	.00065	41	29
Steamed	.26	.0019	107	96
Steamed, held 1 hr.	.20	.0020	83	101

*Results are for samples composited of aliquots from the single sub-samples in successive sets of samples.

Table 3 - Differences* in Per Cent Vitamin Retentions between Stages in the Large-Scale Boiling and Steaming of Carrots, with a Test of their Significance

Description of Samples	Batch Weight	Carotene		Ascorbic Acid				Niacin		Thiamin		Riboflavin	
				Total		Reduced							
	Diff.	Diff.	l.s.d./	Diff.**	l.s.d./	Diff.	l.s.d./	Diff.	l.s.d./	Diff.	l.s.d./	Diff.	l.s.d./
Carrots, Miscellaneous Varieties (Study I)													
Raw, unpeeled - Raw peeled	-20.0	-27	12	-27	9	-30	13	-49	10	-40	12	-40	9
Raw, peeled - Boiled	- 6.3	- 4	10	-73	5	-79	7	-47	4	-50	5	-34	5
Raw, peeled - Boiled plus Boiling Water		- 3	-	-57	6	-	-	- 4	8	- 8	5	22	3
Boiled - Boiled, held	6.2	1	-	- 2	5	- 7	6	1	-	2	6	2	-
Raw, peeled - Steamed	-10.6	-	-	-38	11	-44	13	-16	15	-18	6	- 8	16
Steamed - Steamed, held	1.0	-	-	- 2	-	-16	13	4	-	- 4	9	- 3	-
Steamed - Boiled	-	-	-	-35	9	-35	13	-31	7	-32	8	- 26	11
Steamed, held - Boiled held	-	-	-	-35	10	-26	13	-34	7	-26	9	- 21	9
Carrots, Chantenay Coreless (Study II)													
Raw - Boiled	- 8.1	- 5	4	-58	5	-65	6	-43	2	-44	3	- 30	6
Raw - Boiled plus Boiling Water	-	- 4	-	-31	7	-	-	1	3	- 6	3	12	5
Boiled - Boiled, held	3.5	0	-	- 6	4	-14	3	0	2	2	3	0	3
Raw - Steamed	- 9.3	- 7	-	-37	7	-38	10	-12	3	-16	2	- 8	3
Steamed - Steamed, held	.3	0	-	- 8	5	-24	7	- 2	5	1	2	0	3
Steamed - Boiled	-	-	-	-21	4	-27	6	-31	4	-28	3	- 22	4
Steamed, held - Boiled, held	-	-	-	-19	4	-17	5	-21	4	-27	3	- 22	4

* Differences were derived from per cent vitamin retention values given in Table 1.

** Differences as great as or greater than the value calculated as the least significant difference are considered as significant. These are underlined. A negative sign is used when the vitamin content of the first stage is greater than that of the second stage; no sign is used when the reverse is true.

/ See text for method by which the least significant difference l.s.d. (95%) is calculated.

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APPENDIX

VITAMIN CONTENT, PER CENT DRY SOLIDS, BATCH WEIGHT, AND pH OF CARROTS AND INGREDIENTS AT VARIOUS STAGES IN PREPARATION

Carrots, Boiled and Held, Steamed

Batch I through Batch XIV Miscellaneous Variety

No. Description	Batch Wt. units	Dry Wt. %	pH	Carotene	Asc. Tot.	Acid Red.	Niacin	Thiamin	Riboflavin
				mg./100 gm.					
Batch I									
1. Raw, Unpeeled	122.2	12.6	5.7	10.0	5.93	.52	.74	.058	.044
2. Raw, Peeled	100.0	11.8	6.0	8.35	6.68	.88	.53	.037	.036
3. Boiled	87.9	10.1	6.0	7.27	3.25	.57	.40	.027	.033
4. Boiling Water	89.3	4.3	5.9	.05	1.19	--	.24	.012	.018
5. Boiled, Held	93.0	9.8	5.9	8.25	2.20	.49	.36	.027	.032
Batch II									
1. Raw, Unpeeled	117.9	13.1	6.3	9.9	5.98	.64	.71	.060	.061
2. Raw, Peeled	100.0	12.5	6.4	8.05	5.54	1.17	.68	.043	.041
3. Boiled	90.7	9.8	5.9	10.45	2.02	.54	.39	.026	.032
4. Boiling Water	101.0	5.5	5.7	.06	.66	--	.28	.013	.021
5. Boiled, Held	96.2	9.6	5.8	8.35	1.54	.65	.36	.023	.030
Batch III									
1. Raw, Unpeeled	120.7	13.2	6.3	12.15	5.60	.28	.95	.068	.051
2. Raw, Peeled	100.0	12.4	6.4	13.1	5.83	.18	.74	.054	.051
3. Boiled	89.7	10.5	5.8	11.5	1.88	.32	.38	.029	.036
4. Boiling Water	126.0	4.6	5.7	.03	.85	--	.27	.018	.022
5. Boiled, Held	96.0	9.5	5.8	12.0	2.54	.54	.32	.027	.033
Batch IV									
1. Raw, Unpeeled	117.8	12.9	6.3	10.0	5.10	.77	.77	.058	.050
2. Raw, Peeled	100.0	12.6	6.4	13.2	6.41	.89	.71	.052	.042
3. Boiled	90.9	9.8	5.9	11.9	1.95	.36	.37	.024	.032
4. Boiling Water	92.2	4.7	5.7	.06	.90	--	.33	.021	.022
5. Boiled, Held	98.6	9.2	5.8	11.1	1.95	1.08	.40	.031	.033
Batch V									
1. Raw, Unpeeled	120.7	12.6	6.0	11.35	5.88	.77	.76	.060	.041
2. Raw, Peeled	100.0	13.0	6.4	10.65	5.31	.49	.58	.054	.038
3. Steamed	88.1	12.6	5.9	10.1	3.35	.71	.56	.047	.040
4. Steamed, Held	89.3	12.2	5.9	11.1	3.96	2.30	.58	.047	.038
Batch VI									
1. Raw, Unpeeled	128.4	12.6	5.9		5.17	1.05	.97	.067	.061
2. Raw, Peeled	100.0	11.8	6.4		5.20	.82	.67	.056	.049
3. Steamed	92.3	12.0	6.0		3.16	.75	.61	.050	.046
4. Steamed, Held	91.7	12.7	5.6		3.29	1.22	.67	.052	.046

(Appendix)

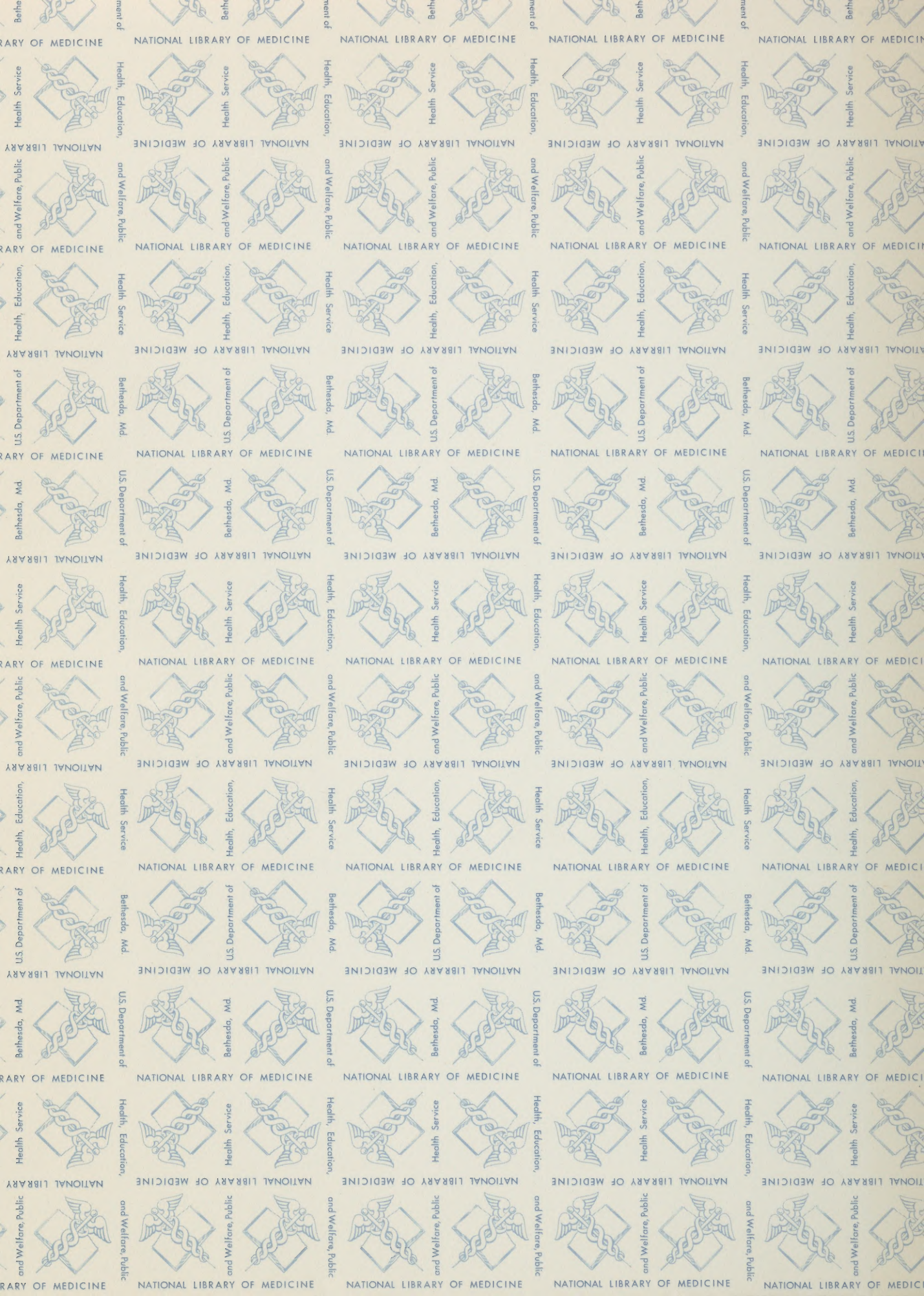
No. Description	Batch Wt. units	Dry Wt. %	pH	Carotene	Asc. Tot.	Acid Red.	Niacin	Thiamin	Riboflavin
				mg./100 gm.					
Batch VII									
1. Raw, Unpeeled	119.3	12.3	6.1		5.83	.75	.69	.057	.046
2. Raw, Peeled	100.0	12.7	6.3		4.29	.45	.63	.052	.044
3. Steamed	87.3	12.5	6.0		3.40	.53	.64	.050	.053
4. Steamed, Held	88.8	13.1	6.0		2.70	1.06	.62	.040	.044
Batch VIII									
1. Raw, Unpeeled	118.2	14.1	6.2		6.17	.90	.92	.060	.050
2. Raw, Peeled	100.0	13.3	6.3		5.72	.50	.79	.058	.045
3. Steamed	89.8	12.2	5.9		4.29	.76	.69	.055	.041
4. Steamed, Held	91.6	13.5	5.8		3.76	1.04	.72	.050	.045
Batch IX									
1. Raw, Unpeeled	115.4	13.3	6.6	12.3	6.81	.48	.89	.076	.057
2. Raw, Peeled	100.0	12.0	6.5	10.85	5.61	1.05	.70	.065	.049
3. Boiled	94.1	9.1	6.1	12.1	1.20	.63	.42	.036	.033
4. Boiled, Held	101.1	8.7	6.0	11.1	.76	.58	.39	.033	.033
5. Boiling Water	108.9	5.1	5.9	.04	.83	--	.36	.028	.025
Batch X									
1. Raw, Unpeeled	116.8	12.7	6.2	10.1	5.87	.26	1.01	.077	.057
2. Raw, Peeled	100.0	11.9	6.4	10.8	5.25	.56	.69	.074	.048
3. Boiled	99.9	8.9	6.0	10.4	1.13	.45	.40	.034	.032
4. Boiled, Held	107.6	8.5	5.9	11.3	1.21	.60	.38	.033	.031
5. Boiling Water	121.1	5.0	5.7	.06	.53	--	.35	.030	---
Batch XI									
1. Raw, Unpeeled	111.0	13.6	6.3	11.8	5.75	1.13	1.20	.082	.046
2. Raw, Peeled	100.0	12.4	6.2	11.3	5.15	.58	.98	.074	.042
3. Boiled	92.1	9.1	5.8	11.8	1.49	.62	.51	.036	.026
4. Boiled, Held	99.5	8.8	5.9	11.6	1.18	.90	.50	.032	.030
5. Boiling Water	113.5	5.3	5.7	.04	1.14	--	.48	.029	.025
Batch XII									
1. Raw, Unpeeled	126.4	12.7	6.2	10.2	5.21	.58	1.46	.080	.050
2. Raw, Peeled	100.0	12.1	6.2	8.8	5.77	.56	1.23	.073	.045
3. Boiled	97.8	9.5	5.8	9.0	1.39	.45	.65	.040	.030
4. Boiled, Held	102.6	9.2	5.8	8.2	1.35	1.00	.68	.040	.028
5. Boiling Water	102.7	5.1	5.7	---	.93	--	.50	.026	.027
Batch XIII									
1. Raw, Unpeeled	125.7	13.1	6.2	12.5	5.81	.18	1.15	.083	.053
2. Raw, Peeled	100.0	12.3	6.4	11.9	5.60	1.24	1.00	.073	.045
3. Boiled	97.0	8.4	6.0	11.3	1.15	.76	.50	.037	.026
4. Boiled, Held	102.0	8.4	5.9	10.5	1.00	.65	.50	.034	.024
5. Boiling Water	144.8	4.5	5.8	--	.85	--	.44	.029	.020

(Appendix)

No. Description	Batch Wt. units	Dry Wt. %	pH	Carotene	Asc. Tot.	Acid Red.	Niacin	Thiamin	Riboflavin
				mg./100 gm.					
Batch XIV									
1. Raw, Unpeeled	119.8	12.7	6.2	10.2	5.93	.96	1.14	.075	.053
2. Raw, Peeled	100.0	11.6	6.4	8.9	5.21	1.19	.94	.075	.033
3. Boiled	96.8	9.1	6.0	10.4	1.27	.51	.52	.035	.028
4. Boiled, Held	102.0	8.0	6.0	9.4	.71	.58	.52	.034	.020
5. Boiling Water	136.8	4.3	5.8	--	.38	--	.41	.027	.019
Batch XV through Batch XXIV Chantenay Coreless Variety									
Batch XV									
1. Raw, Unpeeled	100.0	12.1	6.0	7.4	6.4	.48	.70	.063	.065
2. Steamed	88.6	12.4	6.1	--	3.3	.76	.64	.056	.061
3. Boiled	90.9	9.6	6.0	8.0	2.0	.76	.44	.037	.043
4. Steamed, Held	89.8	12.4	6.0	--	3.0	1.80	.64	.059	.066
5. Boiling Water	77.7	4.9	5.8	--	2.4	--	.37	.029	.036
6. Boiled, Held	96.7	9.3	6.0	8.0	2.1	1.52	.42	.037	.041
Batch XVI									
1. Raw, Unpeeled	100.0	13.0	6.2	8.4	6.6	.72	.69	.068	.068
2. Steamed	91.7	12.7	6.0	--	4.34	.45	.68	.063	.065
3. Boiled	92.0	9.9	5.9	8.6	2.84	.73	.46	.043	.044
4. Steamed, Held	91.7	13.1	5.9	--	3.98	1.33	.60	.063	.069
5. Boiled, Held	96.0	10.0	5.9	8.2	2.53	1.43	.42	.043	.044
6. Boiling Water									
Batch XVII									
1. Raw, Unpeeled	100.0	12.6	6.0	9.6	5.82	.17	.68	.066	.063
2. Steamed	91.3	12.8	6.0	--	4.23	.46	.64	.060	.065
3. Boiled	90.9	9.7	6.0	8.9	3.08	.56	.43	.043	.051
4. Steamed, Held	90.0	13.3	6.0	--	4.35	1.29	.67	.063	.068
5. Boiled, Held	93.4	9.6	6.0	8.4	2.78	1.14	.42	.042	.049
6. Boiling Water	85.4	4.7	5.8	--	1.68	--	.33	.029	.031
Batch XVIII									
1. Raw, Unpeeled	100.0	12.2	6.1	7.5	--	--	.64	.065	.060
2. Steamed	90.9	12.2	6.0	--	--	--	.61	.059	.061
3. Boiled	90.9	9.7	5.9	8.8	--	--	.41	.042	.049
4. Steamed, Held	89.0	12.6	6.0	--	--	--	.62	.062	.061
5. Boiled, Held	95.2	9.4	5.9	8.6	--	--	.37	.043	.047
6. Boiling Water	69.8	5.6	5.7	--	--	--	.36	.033	.032
Batch XIX									
1. Raw, Unpeeled	100.0	12.8	6.3	8.4	6.0	.9	.62	.066	.064
2. Steamed	91.0	12.7	6.2	--	4.85	3.7	.59	.064	.061
3. Boiled	92.5	10.0	6.2	8.5	3.12	.81	.39	.039	.049
4. Steamed, Held	90.6	12.8	6.2	--	3.46	1.33	.59	.065	.064
5. Boiled, Held	95.5	9.1	6.1	9.0	2.33	.65	.37	.037	.047
6. Boiling Water	92.8	4.6	6.0	--	1.62	--	.31	.028	.021

(Appendix)

No. Description	Batch Wt. units	Dry Wt. %	pH	Carotene	Asc. Tot.	Acid Red.	Niacin	Thiamin	Riboflavin
				mg./100 gm.					
Batch XX									
1. Raw, Unpeeled	100.0	12.5	6.3	8.9	6.42	.58	.67	.066	.059
2. Steamed	90.0	12.7	6.1	--	4.69	.54	.62	.062	.060
3. Boiled	90.8	9.5	6.2	8.6	2.94	.69	.44	.045	.046
4. Steamed, Held	90.2	12.9	6.1	--	3.77	1.04	.63	.065	.062
5. Boiled, Held	95.2	9.6	6.1	8.2	2.2	1.15	.39	.044	.045
6. Boiling Water	77.7	5.2	6.0	--	1.94	--	.34	.033	.031
Batch XXI									
1. Raw, Unpeeled	100.0	12.0	6.2	8.2	6.4	.45	.61	.069	.054
2. Steamed	91.2	12.1	6.3	--	3.77	.3	.58	.062	.057
3. Boiled	92.2	9.1	6.1	9.0	2.93	.48	.38	.043	.050
4. Steamed, Held	91.8	12.3	6.3	--	3.24	.82	.61	.060	.054
5. Boiled, Held	94.7	8.8	6.1	8.7	2.09	1.13	.35	.040	.042
6. Boiling Water	83.3	4.9	5.9	--	1.95	--	.32	.031	.026
Batch XXII									
1. Raw, Unpeeled	100.0	12.7	6.2	8.6	6.33	.58	.62	.067	.064
2. Steamed	90.5	12.8	6.0	--	4.33	.36	.65	.062	.066
3. Boiled	92.3	9.0	6.0	8.8	2.48	.47	.37	.035	.045
4. Steamed, Held	90.2	12.5	5.9	--	4.16	1.83	.64	.065	.064
5. Boiled, Held	95.3	8.7	6.0	8.2	2.2	1.04	.38	.040	.048
6. Boiling Water	100.5	4.5	5.9	--	1.6	--	.31	.028	.030
Batch XXIII									
1. Raw, Unpeeled	100.0	12.9	6.0	8.8	6.22	.79	.61	.067	.064
2. Steamed	91.3	12.7	5.9	--	4.8	.77	.59	.063	.066
3. Boiled	94.0	9.3	5.9	8.8	2.6	.74	.33	.039	.046
4. Steamed, Held	94.6	11.9	5.9	--	3.83	1.75	.55	.059	.062
5. Boiled, Held	96.9	9.2	5.9	7.5	2.43	1.33	.33	.035	.045
6. Boiling Water	87.7	4.9	5.7	--	1.95	--	.31	.028	.032
Batch XXIV									
1. Raw, Unpeeled	100.0	12.6	6.1	8.4	6.13	.93	.57	.066	.057
2. Steamed	90.4	12.6	6.1	--	4.99	.71	.61	.063	.061
3. Boiled	92.7	9.2	6.0	8.7	3.4	.75	.36	.040	.046
4. Steamed, Held	92.3	12.0	6.0	--	4.31	1.68	.50	.058	.057
5. Boiled, Held	95.6	9.4	6.0	8.7	2.82	1.16	.37	.039	.046
6. Boiling Water	74.3	5.3	5.7	--	2.67	--	--	.032	.032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